the same part of the slit, that these spectra remain distinct, without encroaching on each other. I photographed *Saturn* in 1881, but as I saw Fraunhofer lines only I did not describe it. In my recent photographs the solar lines are well seen, and in these spectra, from about F to N, I am unable to detect any other lines bright or dark. *Saturn* was photographed before it was dark so as to give a very faint sky-spectrum for comparison.

Observations of the Spectrum of Uranus. By Albert Taylor, A.R.S.M., A.N.S.S.

(*Communicated by A. A. Common, F.R.S.*)

On Thursday, May 16, 1889, bright flutings were detected in the spectrum of the planet *Uranus*, by means of a small direct-vision star spectroscope, attached to the 5-foot reflector at Mr. Common's observatory at Ealing. The abundance of light obtained by the great aperture has allowed a more powerful spectroscope to be used since that date, micrometric measurements have been made of the positions of these flutings and bands, and of the dark bands in the spectrum of the planet, and the wave-lengths obtained by the reduction of these measurements are submitted to the Society in this paper.

Professor J. Norman Lockyer had telegraphed early in the month asking for the spectrum to be examined for bright flutings, and on first examination with the 5-foot the most striking features seen were four broad dark bands in the orange, green, greenish-blue, and blue respectively, and between these a series of bright flutings and bands, some of which were sharpest towards the red and others towards the blue end of the spectrum. This compound spectrum was also seen by Mr. Fowler, the demonstrator of astronomy at the Science Schools, South Kensington, who was on a visit to Ealing on May 16. The second dark band from the red end was seen to be the broadest, and was very strong, it and the narrower fourth band (the one in the blue about F) being very much darker than the remaining two. No trace of any solar line or of any narrow line in the spectrum was visible, although the spectrum was very bright, and the slit of the spectroscope was sufficiently narrow to show D as one sharply defined line in a Bunsen's burner (the dispersion being just sufficient to divide the D lines when the narrowest slit is used). As no measurements could be made with any degree of accuracy, and comparisons were difficult, independent light curves were drawn, and on comparison these were found to agree in all the main features. The curves are given in the drawing, and it will be seen that the four dark bands agree in relative position and width; the brightest part of the spectrum

is shown by each as in the green (subsequent measurements of positions giving 5190 as the wave-length), and two other great maxima are in perfect agreement. The only discrepancy between the two curves is in the yellow, and this was cleared up by observations at a later date. There are four submaxima indicated in my curve that Mr. Fowler omitted in his, but they were only seen with great difficulty and after resting the eye for some time.

On May 18 I was able again to observe the spectrum with the direct-vision spectroscope, and to confirm the light curve drawn on the 16th, with the exception of the region of previous discrepancy in the yellow, which I found should be as shown in the third curve. Several comparisons were also tried. The brightest fluting of carbon (517) was found to be nearly, but not exactly, coincident with the brightest fluting in the spectrum of *Uranus*, and the other carbon flutings (564 and 474) were seen to be very near bright flutings in the planet. The D lines of sodium fall **near** a faint dark band, but there is no dark marking or line of any kind exactly at that position in the spectrum of *Uranus*, neither was any other solar line visible, although fine lines were specially searched for. In the blue the spectrum was noted as faint and difficult to observe and represent, the bright bands sometimes appearing separated from the continuous spectrum. Several faint dark bands were seen in addition to the four broad absorptions.

On May 20 and 21, micrometric measurements were made of the dark bands and of the bright flutings and bands. The spectroscope used has one prism of 60°, and two of 30°, with automatic adjustment for minimum deviation. The collimator and observing telescope lenses are 1-inch aperture and $5\frac{1}{2}$ inches focus. The angular dispersion from A to H is 5°, and the eye-piece used magnifies fifteen times. The micrometer has a screw of 100 threads to the inch, and the drum is divided into 100 parts, so that accurate measurements can be made to $\frac{1}{10000}$th of an inch.

With this spectroscope ten dark bands were seen and measured, five of these being very strong absorption bands. Fourteen bright bands and flutings were seen, the positions of twelve of them measured, and a light curve was drawn to show their relative brightness. On no occasion was any narrow line seen, the solar spectrum being found to be entirely absent, although the slit was adjusted to show the b lines divided in the spectrum of magnesium, and narrow lines were specially looked for in the spectrum. The wave-lengths of the limits of the broad dark bands and of the middle of each of the fainter dark ones and of the brightest portions of the bright bands are as follows:—

Dark Bands in the Spectrum of Uranus.

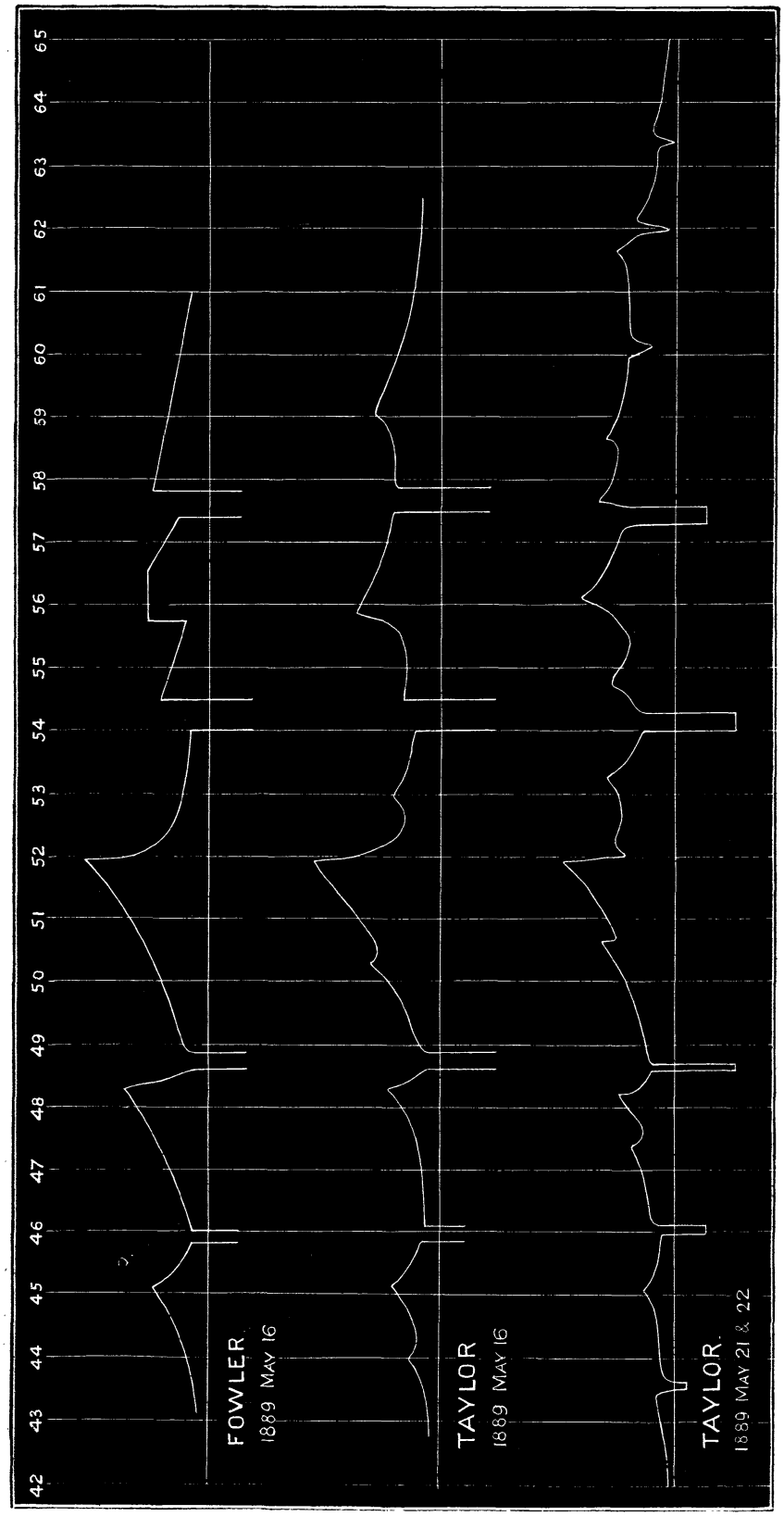
		Wave-lengths.
I.	Very faint dark band	... 6332
II.	Dark band stronger and broader than I.	... 6194
III.	Very faint band (broad)	... 6010
IV.	Very strong band, very broad and apparently of unequal intensity	Begins 5754 Max. 5740 Ends 5730
V.	Very faint and narrow, and close to a bright fluting	... 5543
VI.	Broad band, of equal intensity throughout ...	Begins 5428 Ends 5399
VII.	Rather narrow band at red edge of brightest fluting	Begins 5210 Ends 5200
VIII.	Strong rather broad band of equal intensity throughout	Begins 4868 Ends 4860
IX.	Fairly strong broad band, not so dark as either VIII., VI., or IV.	Begins 4614 Ends 4594
X.	Another faint band, very difficult to measure ...	Begins 4350 Ends ?

The wave-lengths are means of two determinations.

Bright Bands and Flutings.

		Wave-lengths.
I.	Bright fluting, fading towards blue	6170
II.	Bright band, fainter on red edge	5863
III.	Brightening at edge of a dark band, fades towards the red	5761
IV.	Very strong bright band, fairly sharp towards the blue, and fading slightly towards the red	5601
V.	Strong bright band, fading both ways, but most towards the red	5473
VI.	Faint bright band, fading out equally in both directions ...	5302
VII.	Brightest, strongest fluting, sharp on its red edge ...	5190
VIII.	Faint fluting, sharp on its red edge	5068
IX.	Strong fluting, sharp towards red	4826
X.	Faint fluting, sharpest on red edge	4741
XI.	Faint broad band fading both ways, but sharpest to the red	4510
XII.	Faint fluting, sharpest to red	4345
XIII.	Faint band seen occasionally, but not measured... about	4100

There is decidedly another fluting similar to II. in the extreme red (about 635), but it was too faint to be accurately measured. In each case the wave-length given is the mean of three determinations.



Light Curves of the Spectrum of *Uranus*.

Although the term "fluting" is used, it must not be taken as implying that any structure was seen in these bright bands, but rather that the band was sharper at or near one edge than the other. The light curve of the spectrum of *Uranus* has been checked on four nights since May 21, and the drawing of that date confirmed.

On May 21 Mr. Espin, observing at Wolsingham Observatory with his $17\frac{1}{4}$-inch reflector, saw the blue broken up into bright bands and dull shadings, but found it impossible to give the places of these details, if they exist, in a drawing. He was using two compound prisms before an eyepiece of 200 power. Definition good but twilight, and planet low. On May 31 Mr. Crossley saw the spectrum of *Uranus* in the direct-vision spectroscope on the 5-foot reflector at Ealing, and saw most decided bright flutings in the green, yellow, and red, but was not so positive about the blue end of the spectrum. Mr. Bicknell, on June 3, also saw the bright flutings in the green, yellow, and red.

Of course it is an exceedingly difficult matter, and one requiring the utmost care, to distinguish between a bright band and a contrast appearance when a spectrum contains broad dark bands, but the bright flutings in *Uranus* are quite distinct from contrast appearances, and are so prominent as to be unmistakable.

I find Dr. Huggins and Dr. Vogel, although they measured the positions of the dark bands, do not seem to have noticed the bright flutings; but Secchi, in his light curve, seems to have had a distinct impression of the brightest fluting. This latter is more marked in his drawing of the light curve of the spectrum of *Neptune*.

The presence of bright flutings in the visual spectrum of *Uranus*, and the absence of any trace of the solar spectrum (on which point all observers agree), indicate that we must considerably modify our ideas as to the physical condition of this planet (and most probably of *Neptune* also), for there can be very little doubt that it is to a large extent self-luminous. It is interesting, perhaps, in this matter to call attention to the fact that *Uranus* is of about the sixth magnitude, yet the photometric intensity of the light of the Sun at *Uranus* is only about $\frac{1}{360}$th of that at the surface of the Earth. Of course we know nothing whatever of the reflecting power of *Uranus*, but if the light is entirely solar the absence of solar lines in the fairly bright visual spectrum will be difficult to explain, whereas if the light is to a large extent intrinsic this absence is fully accounted for.

Comparison of the Spectrum, between C and D, of a Sun-spot, observed May 27, 1884, with another of May 7, 1889. By Rev. S. J. Perry, D.Sc., F.R.S., and Rev. A. L. Cortie.

As the observations of the spectra of sun-spots at the red end of the spectrum have been rare during the time of minimum, we give in the present paper the results obtained on May 6 and 7 of the present year. All the lines between D and *w.-l.* 6474·85, very near C, were carefully examined, and their widening estimated in tenths of the normal breadth of the respective lines. The instrument used was the Browning automatic spectroscope, a dispersion of twelve prisms of 60° being employed. The definition was good, and the lines were all identified on Ångström's map. The spot had appeared on the limb on May 5, and disappeared about the 11th. The general absorption on the 6th was moderate, and on the 7th the spot was evidently breaking up. The following table contains a comparison of these observations, with the spectrum of a sun-spot near the epoch of spot maximum, taken under precisely the same conditions on May 27, 1884. This latter spot was very black, with a dark general absorption. Its spectrum had been previously observed on April 4, and it had reached its quiet stage after two solar revolutions. In Table I. the first column gives the wave-lengths of the lines taken from the British Association Catalogue (1878), and in the second and third columns are the observed amounts of widening in the two spots. The lines seen bright in the chromosphere by Professor Young are marked by an asterisk. In the remarks, A., B., F., S., K., L. and D. refer to the maps and numbers of Angström, Burton, Fievez, Piazzi Smyth, Kirchhoff, Liveing and Dewar. In Table II. are collected the results for the different metals. In drawing up this table the coincidences have been taken from Ångström's map, and the British Association Catalogue (1878). A few lines also have been admitted from Watts' Index of Spectra, when the positions were very close, always less than one tenth-metre.

TABLE I.

Lines between C and D observed in two Sun-spots.

Wave-length.	1884, May 27,	1889, May 6 and 7.	Remarks.
6562·10 C	0	0	
45·40	0·4	...	
*15·80	0·5	...	
11·64	...	...	
6498·25	0·6	...	
*96·31	0·4	...	